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(54) Abstract Title
A robot cleaner and a method for controlling a robot cleaner system

(57) A robot cleaner (10) for performing cleaning in accordance with command signals received from external apparatus (4) comprises a driving unit (15) for driving a plurality of wheels on a body (40a) of the cleaner; an upper camera (14) disposed on the main body, the upper camera being arranged to generate an image of an area generally perpendicular to the driving direction of the cleaner; and a controller (18) for controlling the driving unit so that the cleaner moves within a cleaning area (21) by following a predetermined driving path (22). The controller (18) also compensates for errors and deviations from the driving path by analysing the image generated by the upper camera (14). The cleaner (1) can thus recognise its position more accurately since position recognition makes use of an images taken from above the robot cleaner, which image exhibits less variety in terms of object or obstacles than an image of a floor area. Therefore, movement error is reduced and cleaning work can be performed more easily and more efficiently.

FIG.2

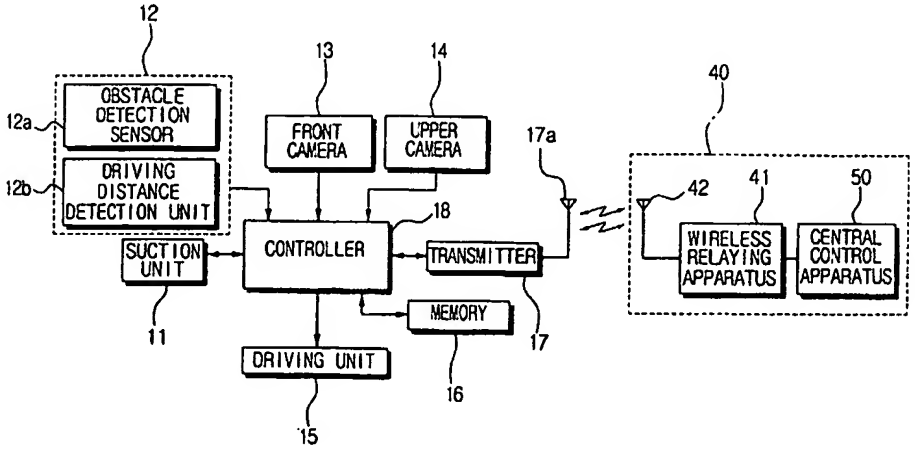

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FIG. 1

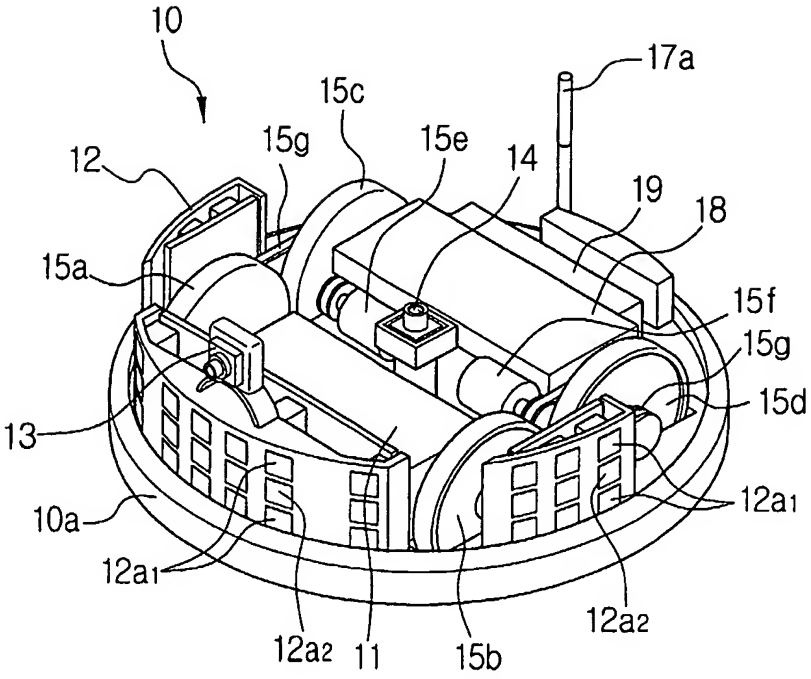

10
17a
15c
15g
15e
14
12
19
18
15a
15f
15g
15d
13
10a
12a1
12a1
12a2
11
15b
12a2

FIG.2

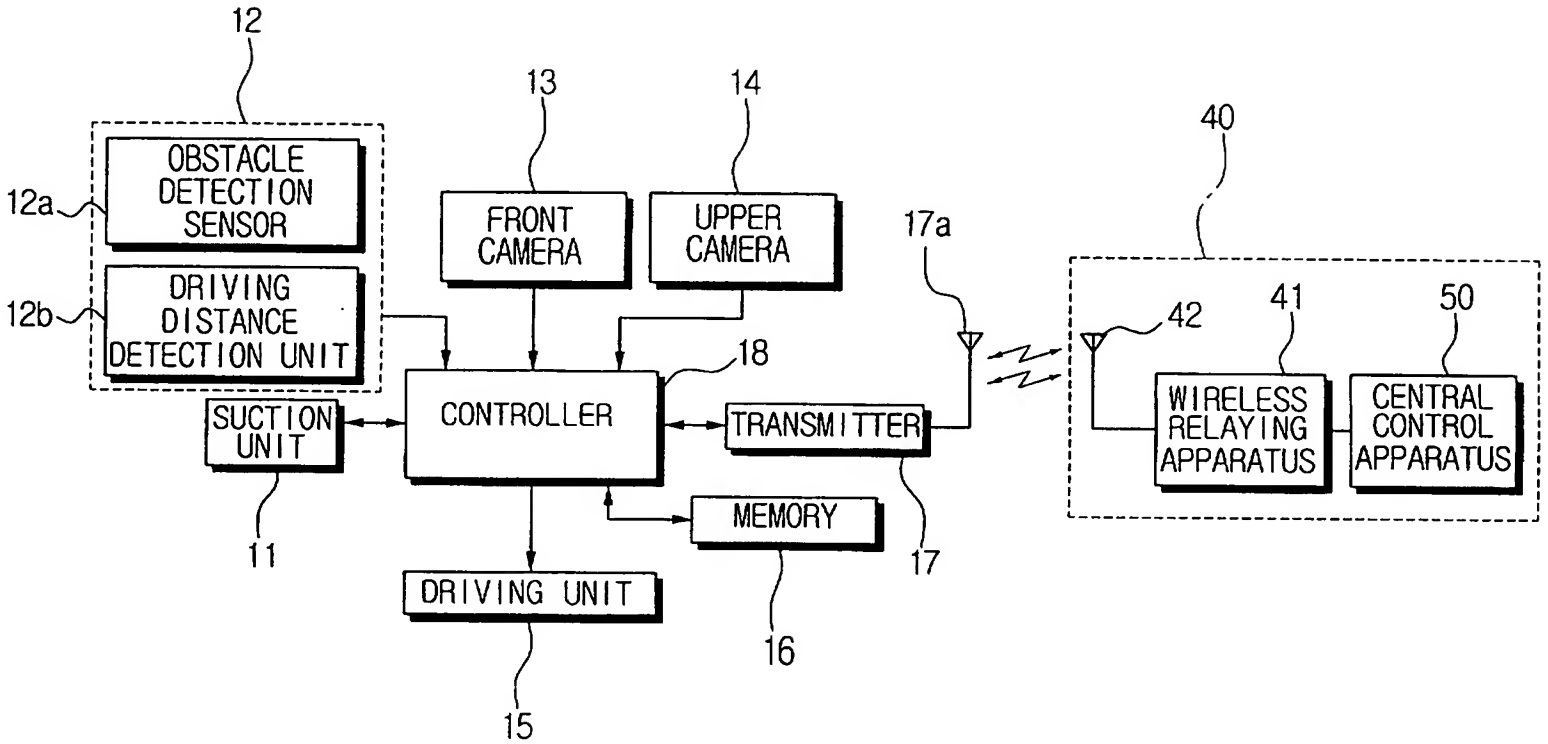

12
13
14
40
OBSTACLE DETECTION SENSOR
12a
FRONT CAMERA
UPPER CAMERA
17a
DRIVING DISTANCE DETECTION UNIT
12b
42
41
50
18
SUCTION UNIT
CONTROLLER
TRANSMITTER
WIRELESS RELAYING APPARATUS
CENTRAL CONTROL APPARATUS
MEMORY
11
17
DRIVING UNIT
16
15

FIG.3

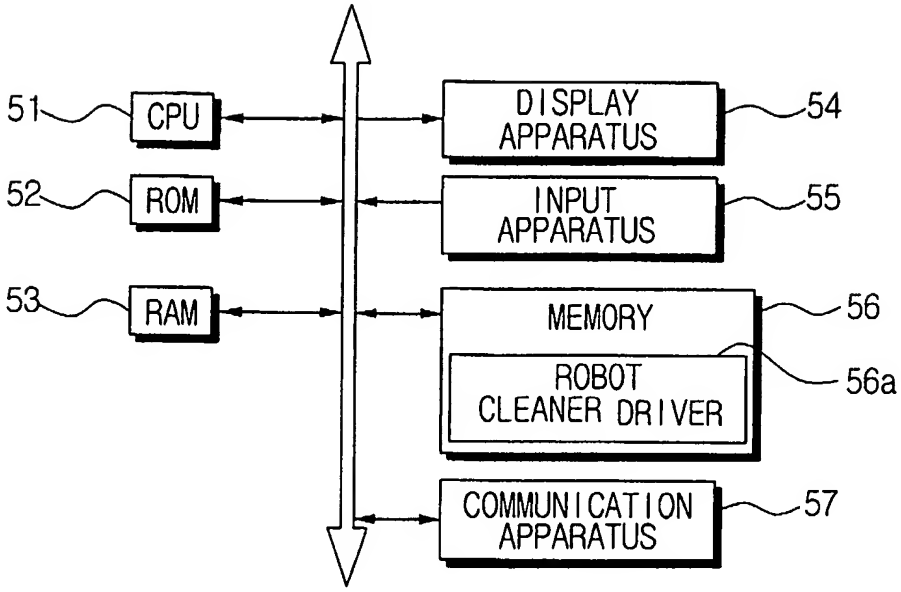

51
CPU
52
ROM
53
RAM
DISPLAY APPARATUS
54
INPUT APPARATUS
55
MEMORY
56
ROBOT CLEANER DRIVER
56a
COMMUNICATION APPARATUS
57

FIG.4

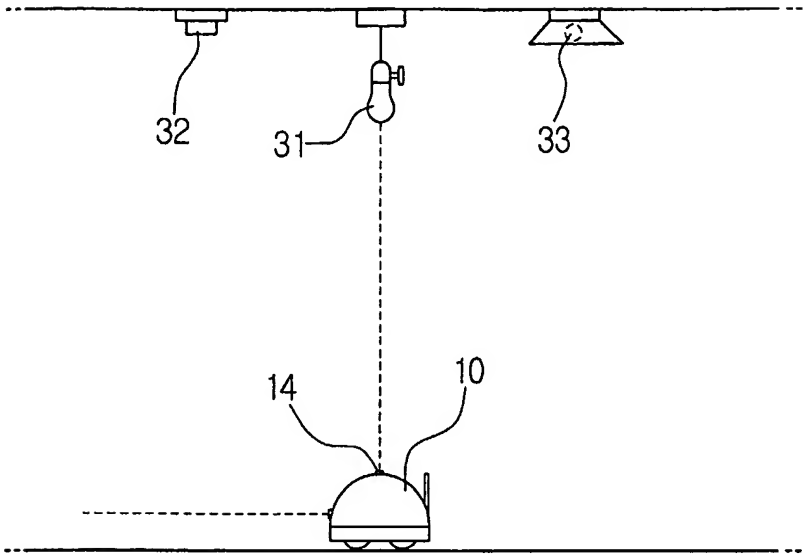


FIG.5

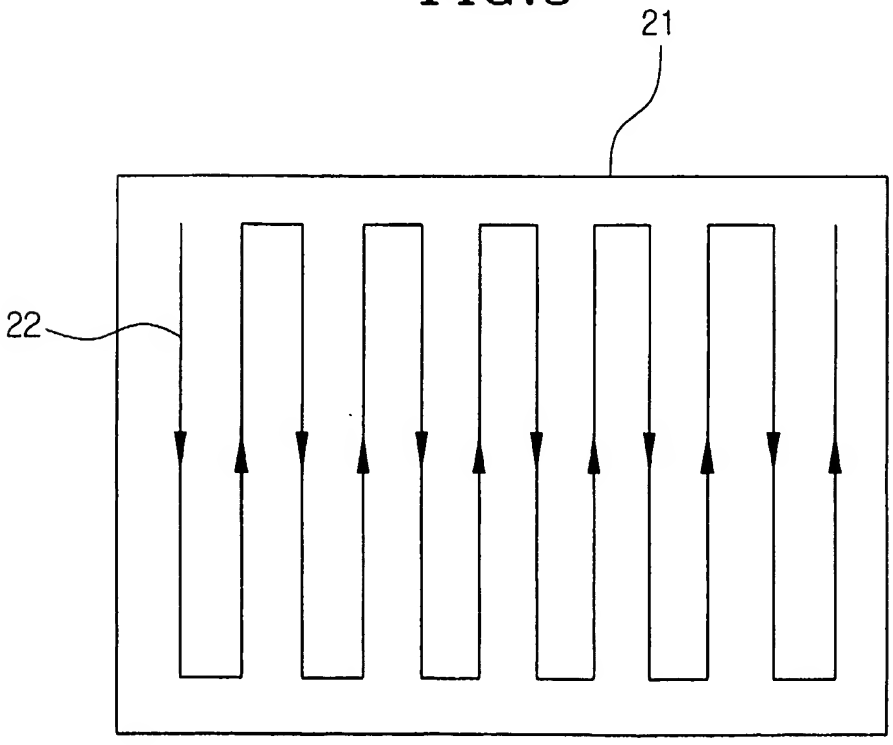


FIG.6

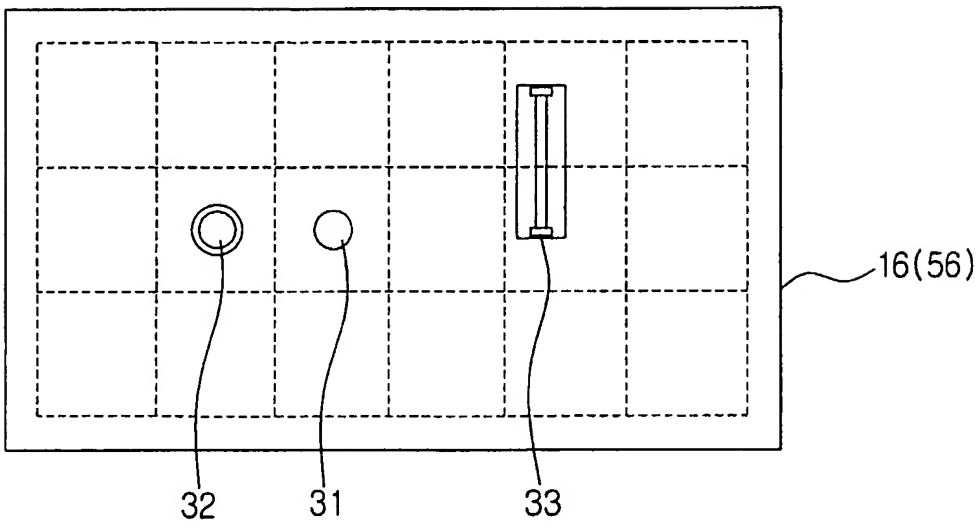


FIG.7

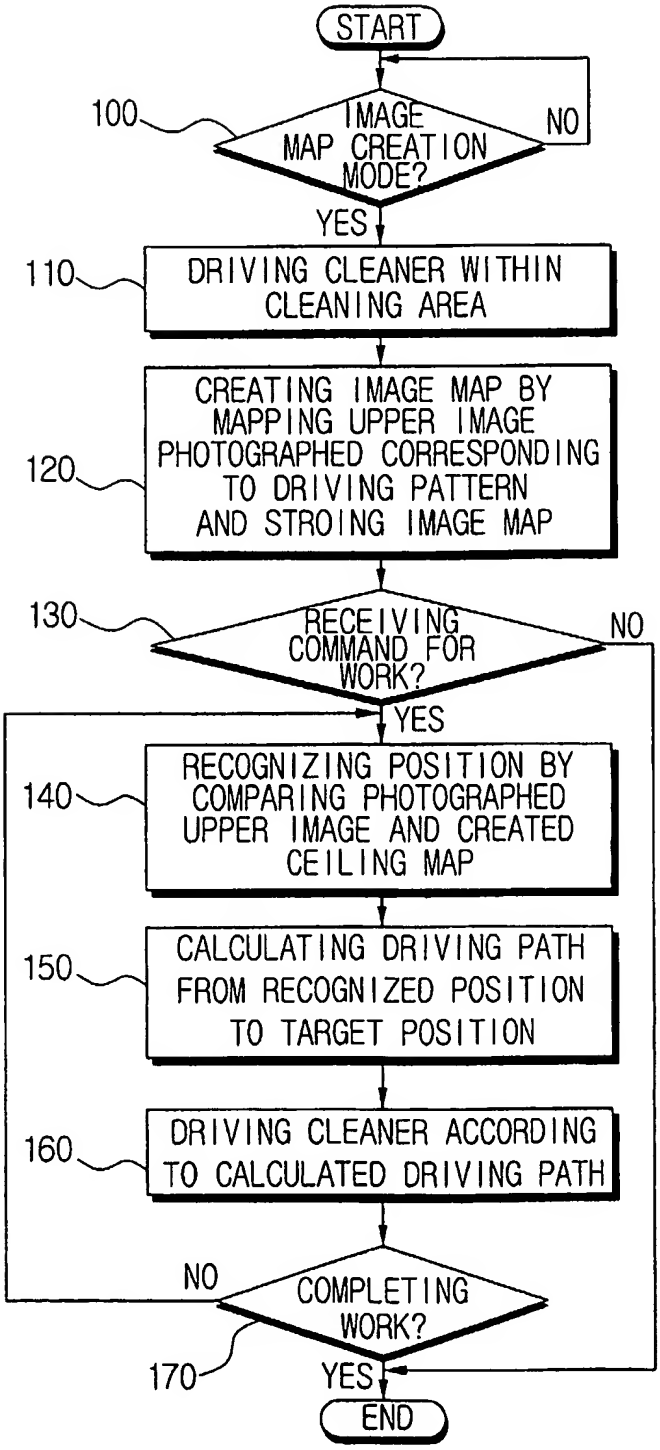

START
100
IMAGE MAP CREATION MODE?
NO
YES
110
DRIVING CLEANER WITHIN CLEANING AREA
120
CREATING IMAGE MAP BY MAPPING UPPER IMAGE PHOTOGRAPHED CORRESPONDING TO DRIVING PATTERN AND STROING IMAGE MAP
130
RECEIVING COMMAND FOR WORK?
NO
YES
140
RECOGNIZING POSITION BY COMPARING PHOTOGRAPHED UPPER IMAGE AND CREATED CEILING MAP
150
CALCULATING DRIVING PATH FROM RECOGNIZED POSITION TO TARGET POSITION
160
DRIVING CLEANER ACCORDING TO CALCULATED DRIVING PATH
NO
COMPLETING WORK?
170
YES
END

FIG.8

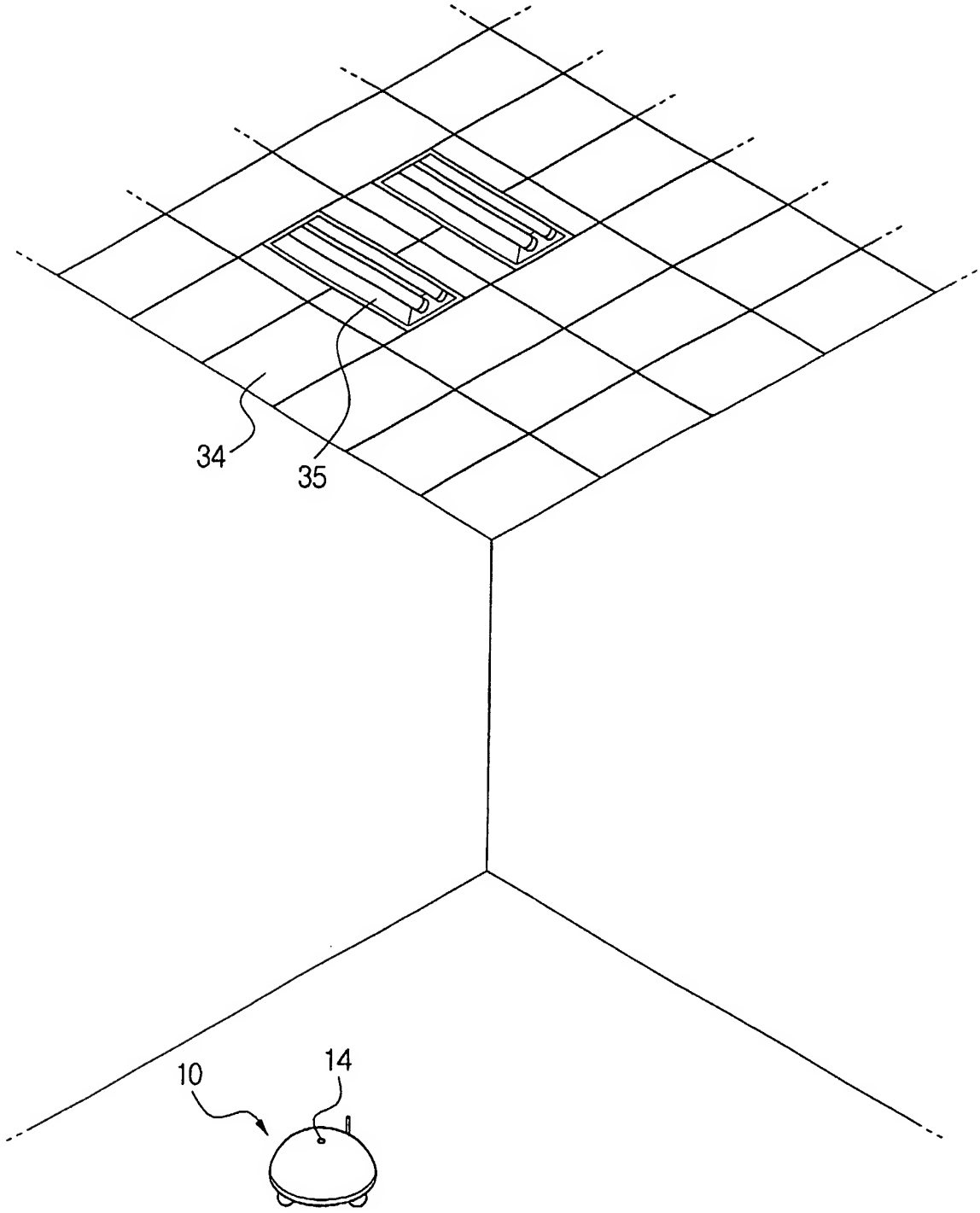
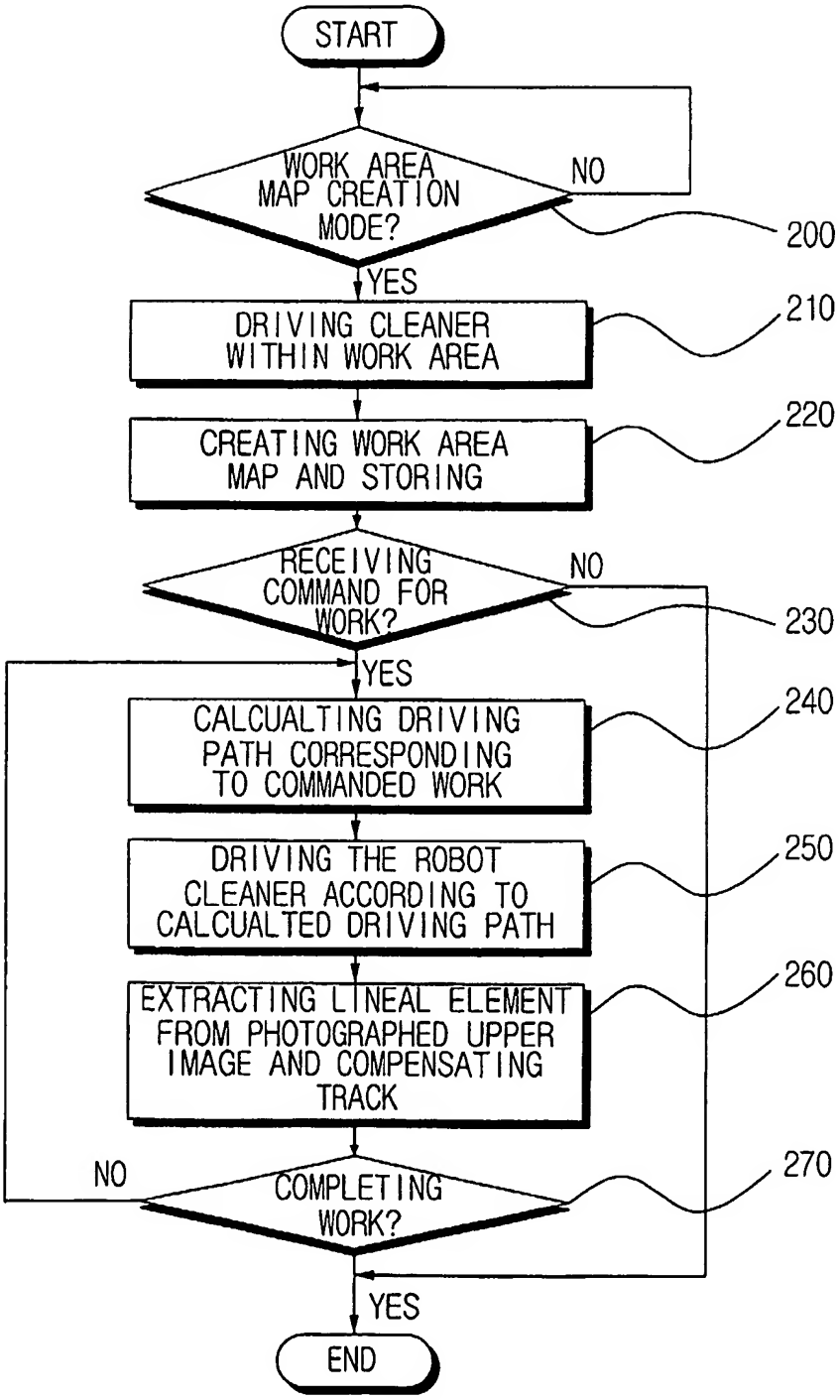


FIG.9


START
WORK AREA MAP CREATION MODE?
NO
200
YES
DRIVING CLEANER WITHIN WORK AREA
210
CREATING WORK AREA MAP AND STORING
220
RECEIVING COMMAND FOR WORK?
NO
230
YES
CALCUALTING DRIVING PATH CORRESPONDING TO COMMANDED WORK
240
DRIVING THE ROBOT CLEANER ACCORDING TO CALCUALTED DRIVING PATH
250
EXTRACTING LINEAL ELEMENT FROM PHOTOGRAPHED UPPER IMAGE AND COMPENSATING TRACK
260
NO
COMPLETING WORK?
270
YES
END

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A ROBOT CLEANER, A ROBOT CLEANING SYSTEM AND A METHOD FOR CONTROLLING A ROBOT CLEANER AND SYSTEM

The present invention relates to a robot cleaner, a robot cleaning system, and to a method of controlling a robot cleaner and robot cleaning system, particularly where the robot cleaner is controlled according to an image captured whilst the robot cleaner is moving.

A known robot cleaner determines the area it needs to clean by driving along an outer track of the cleaning area (which is surrounded by a wall or some obstacle) using an ultrasonic sensor which is disposed on a main body of the cleaner. The cleaner plans a cleaning path to clean within the cleaning area. Then, the robot cleaner drives wheels mounted on its body to move along the cleaning path. The robot cleaner calculates the required driving distance and its current position from a signal which is received from a sensor which senses (i) the number of rotations through which the wheels turn, and (ii) their rotation angle.

However, this system for recognising the robot cleaner's position often results in errors when calculating the driving distance and the position. In other words, there is an error between the figure calculated using the signal from the sensor, and the actual driving distance and position. This is because the wheels can slip, and the floor may be uneven. Indeed, the further the robot cleaner moves, the greater the accumulated error.

A cleaner using information containing such errors may deviate from its planned cleaning path. Consequently, some of the area to be cleaned is not cleaned, and the cleaner may perform several cleaning passes over the same area. Accordingly, cleaning efficiency is reduced.

According to a first aspect of the invention, there is provided a robot cleaner for performing a cleaning operation in accordance with commands received over a wireless link, the cleaner comprising: a driving unit for driving a plurality of wheels attached to

a body of the cleaner; an upper camera disposed on the body and arranged to photograph an image of an area which is above the body and which is located generally perpendicularly to a driving direction of the body; and a controller for controlling the driving unit and arranged to cause the cleaner to move within a cleaning area so as to follow a predetermined driving path, the controller also being arranged to compensate for deviations from the driving path by analysing the image photographed by the upper camera.

According to a second aspect of the invention, there is provided a robot cleaning system comprising: a robot cleaner having a body; an upper camera disposed on the body for photographing an image of an area which is above the body and which is located generally perpendicularly to the driving direction of the cleaner; a remote controller for wirelessly communicating with the robot cleaner, and a driving unit for driving a plurality of wheels on the body; wherein the remote controller is arranged to control the cleaner so as to move within a cleaning area according to a predetermined driving path, and to compensate for deviations from the driving path by analysing the image photographed by the upper camera.

According to a third aspect of the invention, there is provided a method for controlling a robot cleaner, the cleaner having an upper camera for photographing an upper image of an area generally above the body of the cleaner, the method comprising the steps of: creating an image map relating to the area photographed by the upper camera, the image map being created by driving the cleaner within a cleaning area according to a predetermined driving path; recognising the position of the cleaner by comparing the image map with an image currently photographed by the upper camera; calculating a driving path from the recognised position to a target position, when a cleaning signal is received; and driving the cleaner according to the calculated driving path.

According to a fourth aspect of the invention, there is provided a method for controlling a robot cleaner, the cleaner having an upper camera for photographing an upper image of an area generally above the body of the cleaner, the method comprising the steps of: creating a cleaning area map by driving the cleaner within a cleaning area, and then

storing the map when a cleaning area mapping mode is selected; calculating a driving path corresponding to an ordered cleaning operation, when a cleaning signal is received; driving the cleaner according to the calculated driving path; and compensating for deviations from the driving path by analysing an image photographed from the upper camera.

According to a fifth aspect of the invention, there is provided a robot cleaner for performing a cleaning operation, the cleaner comprising: a body having movement means disposed thereon, the movement means being arranged to move the cleaner over an underlying surface; and a first camera disposed on the body, the first camera being configured to photograph an area generally above the body; and processing means arranged to receive one or more images of the photographed area from the first camera as the cleaner moves along a predetermined driving path over the underlying surface, to recognise deviations from the predetermined driving path using the or each received image, and to control the movement means so that the cleaner moves towards the predetermined driving path.

According to a sixth aspect of the invention, there is provided a robot cleaning system comprising: a robot cleaner for performing a cleaning operation, the robot cleaner comprising: a body having movement means disposed thereon, the movement means being arranged to move the cleaner over an underlying surface, a first camera disposed on the body, the first camera being configured to photograph an area generally above the body, and a transceiver for receiving command signals from a remote device; and a remote controller for transmitting control signals over a wireless link to the cleaner, to receive one or more images from the first camera of the cleaner as the robot cleaner moves along a predetermined driving path over the underlying surface, to recognise deviations from the predetermined driving path using the or each received image, and to cause the cleaner to move towards the predetermined driving path.

According to a seventh aspect of the invention, there is provided a method for controlling a robot cleaner, the robot cleaner having a body and a first camera for photographing an area generally above the body, the method comprising: moving the

cleaner over a predetermined driving path on an underlying surface; receiving one or more images of the photographed area from the first camera; recognising deviations of the movement of the cleaner from the predetermined driving path by recognising the current position of the cleaner and determining whether the current position is on the predetermined driving path; and controlling the movement of the cleaner so that it moves towards the predetermined driving path.

Thus, there is provided a robot cleaner, a robot cleaning system, and a method for controlling the same, capable of effectively performing a cleaning operation by compensating for error or deviation in a driving track, and for accurately recognising the current position of the robot cleaner.

It is preferable that the controller controls the driving unit so as to drive the robot cleaner within a cleaning area in accordance with a predetermined driving path and to create an image map relating to the area above the robot cleaner using the or each image generated by the upper camera. This can be done in a cleaning area mapping mode. In addition, the controller can recognise its position by comparing the image map and the image currently being input from the upper camera. The controller then controls the driving unit so that the cleaner follows a target driving path from its recognised position when a cleaning command signal is received.

The controller may create the image map whenever the cleaning command signal cleaning is input or transmitted.

A front camera may be provided on the main body, the front camera being configured to photograph an area ahead of the cleaner in the driving direction to produce a front image. The controller can create the image map by three-dimensionally mapping both the upper image and the front image.

The controller may be arranged to divide the image map into a plurality of cells of a predetermined size, and then identify to a special feature in each of the cells. The controller can then set up the identified feature, or features, as standard coordinate

points for recognising the position of the cleaner. The feature can be at least one of a bulb, a fire sensor, a fluorescent lamp, or a speaker.

The controller can be arranged to extract linear elements or features from the upper image whilst the robot cleaner is moving, and to compensate driving track errors or deviations using the extracted linear elements or features.

The invention will now be described, by way of example, with reference to the drawings, in which:

Figure 1 is a perspective view of a robot cleaner, with the cover of the robot cleaner removed from a base member of the cleaner;

Figure 2 is a block diagram of a robot cleaning system;

Figure 3 is a block diagram of a central control unit, shown in Figure 2;

Figure 4 is a side view of the robot cleaner of Figure 1, positioned in a room;

Figure 5 is a plan view, showing a cleaner movement track within the room shown in Figure 4;

Figure 6 is one example of an image map generated by mapping images which are produced as the robot cleaner moves along the movement track shown in Figure 5;

Figure 7 is a flow chart detailing a preferred control process of the robot cleaner;

Figure 8 is a perspective view showing a further room, including the room's ceiling; and

Figure 9 is a flow chart detailing a further preferred control process of the robot cleaner.

Referring to both Figures 1 and 2, a robot cleaner 10 comprises a suction unit 11, a sensing unit 12, a front camera 13, an upper camera 14, a driving unit 15, a memory 16, a transmitter 17, and a controller 18. Reference numeral 19 indicates a battery.

The suction unit 11 is installed on a main body 10a of the cleaner 10 and is arranged to collect dust on an underlying floor surface by drawing-in air. The suction unit 11 can be of a known construction. For example, the suction unit 11 can include a suction motor (not shown) and a suction chamber for collecting dust from the air which is drawn in through a suction hole or pipe positioned adjacent the floor surface.

The sensing unit 12 is arranged to send an electrical signal to an external location. The sensing unit 12 comprises an obstacle detection sensor 12a, disposed at a side region of the body $10a_1$, arranged to receive reflected signals, and a driving distance sensor 12b, for measuring the distance over which the cleaner moves.

The obstacle detection sensor 12a has a plurality of infrared elements $12a_1$ arranged to project infrared rays, and a plurality of light-receiving elements $12a_2$ for receiving the reflected rays. The infrared elements $12a_1$ and the light-receiving elements $12a_2$ are disposed along an outer circumferential region of the obstacle detection sensor 12a and are grouped in pairs. Alternatively, the obstacle detection sensor 12a can be in the form of an ultrasonic sensor capable of projecting or emitting ultrasonic sounds (ultrasound) and of receiving the reflected ultrasound. The obstacle detection sensor 12a is also used for measuring the distance between the cleaner and an obstacle or wall.

The driving distance sensor 12b can be in the form of a rotation sensor, i.e. a sensor which detects the number of rotations of the wheels 15a to 15d. For example, the rotation sensor can be an encoder which detects the number of rotations of the motors 15e, 15f.

The front camera 13 is disposed on the main body 10a, and points generally towards the front of the robot cleaner 10 (i.e. in the direction of forwards movement of the robot cleaner). The front camera 13 is arranged to capture an image representing the view in front of the robot cleaner. This captured front image is fed to the controller 18.

The upper camera 14 is disposed on the main body 10a, and points generally upwards from the robot cleaner 10. The upper camera 14 is arranged to capture an image representing the view above the robot cleaner. This upper image is fed to the controller 18.

The driving unit 15 comprises: first and second wheels 15a, 15b, disposed either side of the front portion of the robot body 10a; third and fourth wheels 15c, 15d, disposed either side of the rear portion of the robot body; motors 15e, 15f for respectively rotating the wheels 15c, 15d at the rear portion of the robot body; and a timing belt 15g for transmitting power which is applied to the wheels 15c, 15d at the back portion, to the wheels 15a, 15b at the front portion. The driving unit 15 independently drives the motors 15e, 15f in either a forwards or reverse direction in accordance with a control signal from the controller 18. The rotation can be performed by commanding the motors to rotate a different number of times.

The transmitter 17 receives signals by means of an antenna 17a, and transmits signals received through the antenna 17a to the controller 18.

The controller 18 processes the received signals and controls each of the elements accordingly. The controller 18 can process a key signal input, generated from a key input apparatus. The key input apparatus may comprise a plurality of keys which can be operated to set-up various functions of the apparatus. The key input apparatus can be provided on the main body 10a of the robot cleaner 10.

The controller 18 determines a driving path for the robot cleaner 10 by analysing images captured by the upper camera 14 whilst the controller 18 controls the driving unit 15 to move the robot cleaner within a cleaning area according to a particular driving pattern (determined by an input cleaning command).

From the image which is captured by the upper camera 14, the controller 18 generates an image map corresponding to the area above the robot cleaner. To do this, the controller 18 controls the driving unit 15 so as to drive the robot cleaner 10 within the

cleaning area in accordance with a predetermined driving pattern (which is used for creating the image map). Once created, the image map is stored in the memory 16. This is performed when an 'image map creation mode' is selected. The controller 18 can be configured to enter the 'image map creation mode' when a suitable signal is received from an external device, which can be done over a wireless link, or through the key input apparatus mentioned above. Alternatively, the controller 18 can be configured to enter the 'image map creation mode' before performing a cleaning operation, either when a command for cleaning is transmitted wirelessly from an external device, or when the command is received from a key input apparatus.

The controller 18 controls the driving unit 15 to follow the driving pattern set up for the purpose of photographing the cleaning area (which is usually surrounded by an obstacle or wall). In other words, the layout of an entire room is read by the upper camera 14 when the 'image map creation mode' is operated.

As an example of a suitable driving pattern, the controller 18 may advance the robot cleaner 10 in a forwards direction from its current position, and when a wall or obstacle is detected by the obstacle sensor 12a, that current position is set up as an 'initial position'. Next, the controller 18 controls the driving unit 15 so as to drive the robot cleaner 10 along the wall until the robot cleaner 10 returns to the 'initial position'. The controller 18 drives the robot cleaner 10 within the area determined by the previous step, driving the robot cleaner along a driving line made up of regular intervals. For example, the controller 18 can control the driving unit 15 to drive the robot cleaner 10 along the driving line 22 shown in Figure 5. The individual lengths of each part of the driving line 22 allow the captured images to be taken consecutively. The upper images are captured whilst the robot cleaner 10 is moving along the driving line 22.

It is preferable that captured frames are taken such that an overlap rate of 10% to 20% occurs between adjacent images as they are generated or extracted whilst the cleaner 10 is moving. The method for determining such a photograph cycle can be performed using a plurality of images which are photographed several times. The photograph cycle may be set up in advance, taking into account the angle of vision of the upper

camera 14 and the usual distance from floor to ceiling. Then, the photographs can be taken every photographing cycle.

The images taken from the upper camera 14 during the driving process are stored in the memory 16. This forms the upper image map, as shown in Figure 6, the image being distinctive and relating to the particular room shown in Figure 4, since a bulb 31, fire sensor 32, and fluorescent lamp 33 are detected by the upper camera 14.

Preferably, the controller 18 divides the image map (stored in the memory 16) into a plurality of cells. In addition, the controller 18 performs image processing to set up one special or particular feature as a 'standard coordinate point', so that the current position of the robot cleaner 10 can be recognised and used to judge the position of the cleaner 10. This is done by recognising the special feature amongst the images of each of the cells. For example, the bulb 31, the fire sensor 32, and the fluorescent lamp 33 could be selected as the 'special features' in such an image processing operation (in relation to an image map relating to the room having the elements 31, 32, 33 in Figure 4). An image processing method which recognises the special features from the captured image can be one of a number of well-known methods. For example, a method can be used whereby a coordinate point is calculated by connecting pixel points having similar values, the special features being determined after converting the image into a greyscale image. Moreover, an image area having a distribution similar to pre-recorded data values can be used as the special feature, image data distribution data values corresponding to one or more special features being stored in advance.

In a second embodiment, the controller 18 can create the image map by mapping, three-dimensionally, a front image (taken from the front camera 13) and an upper image (taken from the upper camera 14) and storing the image map in the memory 16. When the three-dimensional image map is created, accuracy of the position recognition operation will be improved. In this case, it is preferable that position recognition using the upper image (which will usually have less variety in terms of installed elements) is processed first to recognise the position of the cleaner 10. If the position is not recognised, it is advisable that the image from the front camera is then used.

The controller 18 recognises the position of the cleaner 10 using the image map when the cleaner 10 performs a cleaning operation (after the image map is created). In other words, the controller 18 recognizes the current position of the cleaner 10 by comparing a current image from the upper camera 14 (either alone or with the image from the front camera 13) with the stored image map. The controller 18 controls the driving unit 15 according to a target driving path and using the recognised position. This happens when a signal commanding the cleaning operation is transmitted remotely from an external device, or received from a key input apparatus. The command signal includes a signal for operating the cameras 13, 14 and for cleaning the floor. The controller 18 calculates the driving error using information relating to the current position (recognised from the measured driving distance using the encoder) and by comparing the current image and the stored image map. The driving unit 15 is controlled so that the robot cleaner tracks the target driving path whilst compensating for the calculated driving error.

As mentioned above, the image map can be created directly by the controller 18, and the position of the cleaner 10 can be recognised by the cleaner using the image map so created.

In a third embodiment, a robot cleaning system can be employed to process, externally, the created upper image map and also the position recognition of the robot cleaner 10. This enables the processing burden required of the cleaner 10 to be reduced.

In this case, the cleaner 10 is arranged to send (over a wireless link) the photographed image information to an external device, and to operate in accordance with control signals transmitted from an external device. Specifically, a remote controller 40 wirelessly controls the driving operation of the cleaner 10, recognises the current position of the cleaner 10, and creates the image map.

The remote controller 40 comprises a wireless relay apparatus 41 and a central control unit 50. The wireless relay apparatus 41 receives and processes a signal transmitted (over the wireless link) from the robot cleaner 10, and transmits the processed signal to

the central control unit 50 through a wire or other connection. In addition, the wireless relay apparatus 50 transmits signals received from the central control unit 50, to the robot cleaner 10, by means of an antenna 42.

The central control unit 50 comprises a general computer, as shown in Figure 3. Referring to Figure 3, the central control unit 50 comprises a central processing unit (CPU) 51, a read-only memory (ROM) 52, a random access memory (RAM) 53, a display apparatus 54, an input apparatus 55, a memory 56, and communications apparatus 57.

The memory 56 includes a robot cleaner driver 56a which controls the cleaner 10 and processes signals transmitted from the cleaner 10. The robot cleaner driver 56a runs a menu for setting up control operations of the cleaner 10, the menu being shown by the display unit 54. The robot cleaner driver 56a processes a menu selection command inputted by a user to cause the cleaner 10 to operate accordingly. It is preferable that the menu has a wide number of options including one to allow the creation of the cleaning area map, the cleaning operation, and the sensing or observation operation. Moreover, it is advisable that options are provided for image map creation, for target area selection, and for methods of cleaning, preferably as sub-selection menus.

In the case of a menu relating to the creation of a cleaning area map, or an image map, it is preferable that the user can set up an update cycle for, say, one week or for one month, as an image map update condition.

When a signal relating to the creation of an image map is input through the input apparatus 55, or at the time of creating an image map, the robot cleaner driver 56a controls the robot cleaner 10 to receive upper images relating to the entire cleaning area (which are required for creating the image map), as described previously. The robot cleaner driver 56a creates the image map by mapping the image transmitted as the robot cleaner 10 is controlled, and by storing the created image map into the memory 56. In this case, the controller 18 of the cleaner 10 controls the driving unit 15 in accordance with control information transmitted from the robot cleaner driver 56a, through the

wireless relay apparatus 41, thus omitting or reducing the processing load ordinarily required to create the image map. In addition, the controller 18 transmits the upper image, captured in regular photographing cycles while the cleaner is moving, to the central control unit 50 by means of the wireless relay apparatus 41. The robot cleaner driver 56a may create the image map by mapping both the front and upper images together.

A method of position recognition used by the cleaner 10 when operated according to the above method will now be described with reference to Figure 7.

Firstly, the controller 18 decides whether the mode for creating the image map has been selected (100). If so, the controller 18 drives the robot cleaner 10 so as to photograph the entire upper area (110).

The controller 18 creates an image map by mapping the upper image captured by the upper camera 14 and possibly the front image also. The upper image corresponds to the cleaning area. The image map is stored in the memory 16, 56 (120).

Next, the controller 18 decides whether a command for performing a cleaning operation has been transmitted (130). If so, the controller 18 determines the current position of the robot cleaner 10 by comparing the captured image from the upper camera 14, and the stored image map (140).

When the image map also includes information relating to a front image, in step 140, the currently-viewed front image can also be used for recognising the robot cleaner's current position.

Next, the controller 18 calculates the movement path from the (recognised) current position, for moving the robot cleaner 10 over the cleaning area, or cleaning path, according to the transmitted cleaning command (150).

The controller 18 then causes the cleaner 10 to move according to the movement path so calculated (160).

The controller 18 thereafter determines whether the cleaning operation is complete (170). The cleaning operation here refers to the cleaning work performed whilst the robot cleaner 10 moves along the cleaning path or moves to the target position. If it is determined that the operation is not complete, steps 140 to 160 are repeated until it is determined that the work is complete.

If the ceiling of the room to be cleaned has a rectangular outline, a method for driving the cleaner 10 can be used wherein the processing load for photographing the ceiling is reduced.

As shown in Figure 8, if the ceiling contains an array of ceiling elements such as square or rectangular ceiling tiles or plaster boards 34, or a plurality of direct-light fluorescent lamps 35, the controller 18 and/or the remote controller 40, can be arranged to compensate for driving error by using the fact that the ceiling has a linear outline.

The controller 18 detects the linear features of the image photographed by the upper camera 14 (whilst the robot cleaner 10 is moving) using one of a number of well-known methods for processing images and for detecting edges. The controller 19 follows a driving track using the extracted linear information.

The controller 18 may compensate for detected driving error with respect to a predetermined time or distance using the encoder. Following this, the controller 18 repeatedly compensates for driving error using the linear elements of the image, as captured by the upper camera.

In other words, the controller 18 calculates the driving error by detecting the driving error using the encoder, and then controlling the driving unit 15 to allow the robot cleaner 10 to return to the target driving track according to the calculated error. Following this, the controller 18 compensates for driving error by calculating the track deviation error of the robot cleaner 10 using direction information of linear elements which is/are extracted by analysing the image data from the upper camera 14.

The above described method can be used by the robot cleaning system described previously.

The edge detection image processing method can be one of a number of known methods such as the 'Sobel Alorithm,' or the 'Navatiark Babu Algorithm.'

The control method using driving error compensation (involving the extraction of linear elements from the upper image) will now be described in greater detail with reference to Figure 9.

Firstly, the controller 18 determines whether the mode relating to the creation of the cleaning area map (200) has been selected. If so, the controller 18 drives the robot cleaner 10 to move it within the cleaning area (210).

A robot cleaner movement pattern relating to this mode is then followed, this pattern being the same as that described previously. Firstly, the cleaner 10 moves forwards, and when a wall or obstacle is detected by the obstacle detection sensor 12a, that position is set-up as the initial position. Following this, the controller 18 controls the driving unit 15 which drives the cleaner 10 until a time when the cleaner 10 returns to its initial position, the cleaner being driven around the outline of the room and along the wall. Next, the controller 18 drives the robot cleaner 10 within the area determined by the previous step, along a driving line having predetermined intervals. The controller 18 creates the cleaning area map using information relating to obstacles or using the driving track determined during the driving operation described above. The cleaning area map is then stored (220). Alternatively, the cleaning area map can be created using the same method as for the image map creation mode described above. The map is then stored.

Next, the controller 18 determines whether a cleaning command has been transmitted (230). If so, the controller 18 calculates a driving path for moving the cleaner 10 over the cleaning area or path corresponding to the transmitted cleaning command (240).

Next, the controller 18 drives the cleaner 10 in accordance with the calculated driving path (250).

The controller 18 extracts information relating to linear elements, from the image captured using the upper camera 14, whilst the robot cleaner 10 is moving, and compensates for driving error using the extracted linear element information (260). Here, it is preferable that the analysing process (i.e. of the image taken from the upper camera 14) is performed every set-up cycle so as to reduce the image processing load required.

Next, the controller 18 determines whether the cleaning is complete (270). If it is determined that cleaning has not been completed, the controller 18 repeats steps 240 to 260 until the cleaner 10 has completed cleaning.

As described above, a robot cleaner, a robot cleaning system, and a method for controlling the same enable cleaning work to be performed efficiently by reducing driving error from the desired position or path, since the cleaner 10 is able to recognise its position more accurately using the upper image, which has less variety in terms of installed elements, such as lights, etc.

Claims

1. A robot cleaner for performing a cleaning operation in accordance with commands received over a wireless link, the cleaner comprising:

a driving unit for driving a plurality of wheels attached to a body of the cleaner;

an upper camera disposed on the body and arranged to photograph an image of an area which is above the body and which is located generally perpendicularly to a driving direction of the body; and

a controller for controlling the driving unit and arranged to cause the cleaner to move within a cleaning area so as to follow a predetermined driving path, the controller also being arranged to compensate for deviations from the driving path by analysing the image photographed by the upper camera.

2. A robot cleaner according to claim 1, wherein the controller is further arranged to create an image map relating to the photographed area above the cleaner, whilst operating in a cleaning area mapping mode, the controller being arranged to recognise the position of the robot cleaner by comparing the image map and an image currently being received from the upper camera, the driving unit being controlled such that the cleaner follows a target driving path from its recognised position when a cleaning signal is received.

3. A robot cleaner according to claim 2, wherein the controller is arranged to create the image map when the cleaning signal is received.

4. A robot cleaner according to claim 2 or claim 3, further comprising a front camera disposed on the body and arranged to photograph an image of an area generally in the driving direction of the cleaner,

the controller being arranged to create the image map by three-dimensionally mapping both the upper image photographed from the upper camera, and the front image photographed by the front camera.

5. A robot cleaner according to any of claims 2 to 4, wherein the controller is arranged to divide the image map into a plurality of cells of predetermined size, to identify a feature in each of the cells, and to set up the identified feature as a coordinate point which can thereafter be used for recognising the position of the cleaner.

6. A robot cleaner according to claim 5, wherein the controller is arranged to identify features including at least one of a bulb, a fire sensor, a fluorescent lamp, or a speaker.

7. A robot cleaner according to claim 1, wherein the controller is arranged to extract linear features from the image photographed by the upper camera whilst the cleaner is being driven, and to compensate for driving track error using the extracted linear features.

8. A robot cleaning system comprising:

a robot cleaner having a body;

an upper camera disposed on the body for photographing an image of an area which is above the body and which is located generally perpendicularly to the driving direction of the cleaner;

a remote controller for wirelessly communicating with the robot cleaner, and

a driving unit for driving a plurality of wheels on the body;

wherein the remote controller is arranged to control the cleaner so as to move within a cleaning area according to a predetermined driving path, and to compensate for deviations from the driving path by analysing the image photographed by the upper camera.

9. A system according to claim 8, wherein the remote controller is arranged to create an image map relating to the area generally above the robot cleaner whilst operating in a cleaning area mapping mode, the controller being arranged to recognise the position of the cleaner by comparing the image map with a current image transmitted from the upper camera of the robot cleaner, and to control the cleaning path

of the robot cleaner so that the robot cleaner follows a target path from its recognised position when a cleaning signal is produced.

10. A system according to claim 9, wherein the remote controller is arranged to create the image map when the cleaning signal is produced.

11. A system according to claim 9 or claim 10, further comprising a front camera disposed on the main body, the front camera being arranged to photograph a front image of an area generally towards the driving direction of the robot cleaner,

the remote controller being arranged to create the image map by mapping, in three dimensions, the upper image and the front image transmitted from the robot cleaner.

12. A system according to any of claims 9 to 11, wherein the remote controller is arranged to divide the image map into a plurality of cells of predetermined size, to determine a feature in each of the cells, and to set up the identified feature as a standard image point which can be used for recognising the position of the robot cleaner.

13. A system according to claim 12, wherein the remote controller is arranged to identify features including at least one of a bulb, a fire sensor, a fluorescent lamp, or a speaker.

14. A system according to claim 8, wherein the remote controller is arranged to extract linear features from the image transmitted from the upper camera, and to compensate for driving track error by using the extracted linear element information when controlling the driving of the robot cleaner.

15. A method for controlling a robot cleaner, the cleaner having an upper camera for photographing an upper image of an area generally above the body of the cleaner, the method comprising the steps of:

creating an image map relating to the area photographed by the upper camera, the image map being created by driving the cleaner within a cleaning area according to a predetermined driving path;

recognising the position of the cleaner by comparing the image map with an image currently photographed by the upper camera;

calculating a driving path from the recognised position to a target position, when a cleaning signal is received; and

driving the cleaner according to the calculated driving path.

16. A method for controlling a robot cleaner, the cleaner having an upper camera for photographing an upper image of an area generally above the body of the cleaner, the method comprising the steps of:

creating a cleaning area map by driving the cleaner within a cleaning area, and then storing the map when a cleaning area mapping mode is selected;

calculating a driving path corresponding to an ordered cleaning operation, when a cleaning signal is received;

driving the cleaner according to the calculated driving path; and

compensating for deviations from the driving path by analysing an image photographed from the upper camera.

17. A method according to claim 16, wherein the driving path compensation step extracts linear features from the image photographed by the upper camera, and compensates for deviation from the driving path by using the extracted linear elements.

18. A robot cleaner for performing a cleaning operation, the cleaner comprising:

a body having movement means disposed thereon, the movement means being arranged to move the cleaner over an underlying surface; and

a first camera disposed on the body, the first camera being configured to photograph an area generally above the body; and

processing means arranged to receive one or more images of the photographed area from the first camera as the cleaner moves along a predetermined driving path over the underlying surface, to recognise deviations from the predetermined driving path

using the or each received image, and to control the movement means so that the cleaner moves towards the predetermined driving path.

19. A robot cleaner according to claim 18, wherein the processing means is arranged to perform a set-up operation whereby a plurality of images are received from the first camera, the images being combined to generate an image map representing an area above the underlying surface, the processing means thereafter recognising deviations from the predetermined driving path by recognising the current position of the cleaner by comparing the current image from the first camera with the image map, and determining whether the recognised current position is on the predetermined driving path.

20. A robot cleaner according to claim 19, further comprising a second camera disposed on the body, the second camera being configured to photograph an image of an area generally in the direction of forwards movement of the body, the processing means being arranged to generate a three-dimensional image map in the set-up operation using images received from the first and second cameras.

21. A robot cleaning system comprising:

a robot cleaner for performing a cleaning operation, the robot cleaner comprising: a body having movement means disposed thereon, the movement means being arranged to move the cleaner over an underlying surface, a first camera disposed on the body, the first camera being configured to photograph an area generally above the body, and a transceiver for receiving command signals from a remote device; and

a remote controller for transmitting control signals over a wireless link to the cleaner, to receive one or more images from the first camera of the cleaner as the robot cleaner moves along a predetermined driving path over the underlying surface, to recognise deviations from the predetermined driving path using the or each received image, and to cause the cleaner to move towards the predetermined driving path.

22. A system according to claim 21, wherein the remote controller is arranged to perform a set-up operation whereby a plurality of images are received from the first

camera, the images being combined to generate an image map representing an area above the underlying surface, the remote controller being arranged to thereafter recognise deviations from the predetermined driving path by recognising the current position of the robot cleaner by comparing the current image from the first camera with the image map, and determining whether the recognised current position is on the predetermined driving path.

23. A method for controlling a robot cleaner, the robot cleaner having a body and a first camera for photographing an area generally above the body, the method comprising:

moving the cleaner over a predetermined driving path on an underlying surface;

receiving one or more images of the photographed area from the first camera;

recognising deviations of the movement of the cleaner from the predetermined driving path by recognising the current position of the cleaner and determining whether the current position is on the predetermined driving path; and

controlling the movement of the cleaner so that it moves towards the predetermined driving path.

24. A robot cleaner, constructed and arranged substantially as herein described and shown in the accompanying drawings.

25. A robot cleaning system, constructed and arranged substantially as herein described and shown in the accompanying drawings.

26. A method for controlling a robot cleaner, substantially as herein described with reference to the accompanying drawings.

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Claims searched:	1-13	**Date of search:**	9 October 2002

22

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): A4F: FSDX
G3N: NGA3, NGA9, NGL
G3R: RBD32,

Int Cl (Ed.7): A47L: 9/00
G05B: 13/02, 15/02
G05D: 1/02

Other: Online: EPODOC, JAPIO, WPI, INSPEC

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	GB 2,369,454 A (SAMSUNG KWANGJU ELECTRONICS CO. LTD) See whole document	-

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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